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Date of Application: June 30, 2003

Application Number: Patent Application No. JP 2003-188245

Applicant(s): Matsushita Electric Industrial Co., Ltd.

[Document Name] Patent Application

[Case Number] 2904750007

[Date of Application] June 30, 2003

[Destination] Commissioner of the Japanese Patent Office

[International Patent Classification] A61B 8/00

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[Official Fee]

[Advance Payment Note Number] 139757

[Amount of Payment] 21000

[List of File Documents]

[Name of Document]	Specification	1
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[Name of Document]	Abstract	1

[General Power of Attorney's Number] 0108331

[Proof] Required

[Document Name] SPECIFICATION

[Title of the Invention] ULTRASONIC DIAGNOSTIC APPARATUS

[Claims]

[Claim 1] An ultrasonic diagnostic apparatus, comprising:

a transmission unit that transmits at least one ultrasonic pulse from a surface of a skin of a subject toward a blood vessel of the subject;

a ultrasonic wave reception unit that receives an ultrasonic echo along a depth direction from the surface of the skin and converts the same into an electric signal based on an ultrasonic echo signal reflected by the blood vessel;

a movement detection unit that analyzes a phase of an ultrasonic echo signal in a direction intersecting a center axis of the blood vessel so as to calculate a movement amount of a blood vessel wall; and

a conversion unit that converts a phase change of the ultrasonic echo signal into a hardness value of tissues along the depth direction from the surface of the skin;

a boundary detection unit that detects a boundary position between a blood vessel wall constituting the blood vessel and a blood flow region where blood flows through the blood vessel based on a hardness value of tissues along the depth direction from the surface of the skin.

[Claim 2] The ultrasonic diagnostic apparatus according to the claim 1, wherein the blood vessel wall comprises an anterior wall on a side closer to the transmission unit and a posterior wall on a side farther from the transmission unit, and the ultrasonic diagnostic apparatus further comprising a region of interest placement unit that places the region of interest for obtaining the hardness value of tissues along the depth direction from the surface of the skin so as to lie over at least one of the anterior wall

and the posterior wall.

[Claim 3] The ultrasonic diagnostic apparatus according to claim 1 or 2, wherein the transmission unit transmits a plurality of ultrasonic wave signal along a longitudinal direction of the blood vessel, and the boundary position detection unit detects the boundary position along the longitudinal direction of the blood vessel.

[Claim 4] The ultrasonic diagnostic apparatus according to claim 3, further comprising a filter processing unit provided to perform filter processing of data representing the boundary position along the longitudinal direction of the blood vessel that is detected by the boundary position detection unit.

[Claim 5] The ultrasonic diagnostic apparatus according to claims 1 to 4, further comprising a display unit that displays an image of the blood vessel in cross section along the longitudinal direction of the blood vessel based on the boundary position along the longitudinal direction of the blood vessel that is detected by the boundary position detection unit.

[Claim 6] The ultrasonic diagnostic apparatus according to claims 1 to 5, further comprising an average processing unit provided to perform average processing of data representing the boundary position that is detected by the boundary position detection unit based on data representing a boundary position obtained a predetermined number or more of cycles before.

[Claim 7] The ultrasonic diagnostic apparatus according to claim 6, wherein the predetermined cycles include a heartbeat cycle of a blood flow that flows through the blood vessel.

[Claim 8] The ultrasonic diagnostic apparatus according to claims 1 to 7, further comprising an average processing unit provided to perform

average processing of data representing the movement amount of the blood vessel wall that is detected by the movement detection unit based on data representing the movement amount obtained a predetermined number or more of cycles before.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an ultrasonic diagnostic apparatus that has a function of diagnosing a state of blood vessels using ultrasonic waves.

[0002]

[Prior Art]

As a method of detecting a boundary of a blood vessel wall using ultrasonic waves is disclosed in JP 2000-271117 A. This method measures a displacement and a diameter of the blood vessel, a thickness of a blood vessel wall and the like can be measured based on a maximum peak value and a second peak value of a brightness signal in a image data obtained based on ultrasonic waves reflected by the blood vessel, assuming that a blood vessel has a normal structure.

[0003]

[PATENT DOCUMENT 1]

JP 2000-271117 A

[0004]

[Problems to be Solved by the Invention]

In the above-described conventional technologies, however, since the brightness signal of image data is utilized for analyzing a structure of the blood vessel wall as a target of the measurement, if a brightness of an inner

membrane of the blood vessel wall as the target of the measurement is low, there is a problem that the displacement and the diameter of the blood vessel, the thickness of the blood vessel wall and the like cannot be measured correctly.

[0005]

In addition, in the above-mentioned conventional technologies, the measurements are based on the assumption that the structure of the blood vessel wall as the target of the measurement has a normal structure. Therefore, there is a problem that the displacement of the blood vessel or the like cannot be measured correctly if there is a local lesion such as an atheroma in a blood vessel as a target of the measurement.

[0006]

It is an object of the present invention to provide an ultrasonic diagnostic apparatus that is capable of measuring a state of a blood vessel correctly using ultrasonic waves.

[0007]

An ultrasonic diagnostic apparatus according to the present invention includes: a transmission unit that transmits at least one ultrasonic pulse from a surface of a skin of a subject toward a blood vessel of the subject; an ultrasonic wave reception unit that receives an ultrasonic echo along a depth direction from the surface of the skin and converts the same into an electric signal based on an ultrasonic echo signal reflected by the blood vessel; a movement detection unit that analyzes a phase of an ultrasonic echo signal in a direction intersecting a center axis of the blood vessel so as to calculate a movement amount of the blood vessel wall; and a conversion unit that converts a phase change of the ultrasonic echo signal into a hardness value of tissues along a depth direction from the surface of

the skin; a boundary position detection unit that detects a boundary position between the blood vessel wall constituting the blood vessel and a blood flow region where blood flows through the blood vessel based on a hardness value of tissues along the depth direction.

[0008]

With this configuration, based on a hardness value of tissues along the depth direction from the surface of the skin, the boundary position between the blood vessel wall constituting the blood vessel and the blood flow region where the blood flows through is detected using the boundary position detection unit. Thus, the boundary position between the blood vessel wall and the blood flow region can be detected correctly without the influence of a variation in brightness value of an inner membrane existing in the subject even in the case where there is a local lesion such as an atheroma in the blood vessel.

[0009]

Preferably, an ultrasonic diagnostic apparatus according to the present invention includes that the blood vessel wall has an anterior wall on a side closer to the transmission unit and a posterior wall on a side farther from the transmission unit, and the ultrasonic diagnostic apparatus further includes a region of interest placement unit that places a region of interest (ROI) for obtaining the hardness value of tissues along the depth direction from the surface of the skin so as to lie over at least one of the anterior wall and the posterior wall. With this configuration, the boundary position between the blood vessel wall and the blood flow region can be detected.

[0010]

Preferably, an ultrasonic diagnostic apparatus according to the present invention includes that the transmission unit transmits a plurality

of ultrasonic wave signals along a longitudinal direction of the blood vessel, and the boundary position detection unit detects the boundary position along the longitudinal direction of the blood vessel. With this configuration, a thickness distribution can be obtained along the longitudinal direction of the blood vessel.

[0011]

Preferably, an ultrasonic diagnostic apparatus according to the present invention further includes a filter processing unit provided to perform filter processing of data representing the boundary position along the longitudinal direction of the blood vessel that is detected by the boundary position detection unit. With this configuration, the influence of noise mixing into boundary detection of the blood vessel wall can be minimized.

[0012]

Preferably, an ultrasonic diagnostic apparatus according to the present invention further includes a display unit that displays an image of the blood vessel in cross section along the longitudinal direction of the blood vessel based on the boundary position along the longitudinal direction of the blood vessel that is detected by the boundary position detection unit. With this configuration, a cross section along the longitudinal direction of the blood vessel can be recognized visually.

[0013]

Preferably, an ultrasonic diagnostic apparatus according to the present invention further includes an average processing unit provided to perform average processing of data representing the boundary position that is detected by the boundary position detection unit based on data representing a boundary position obtained a predetermined number or more

of cycles before. With this configuration, the stability of the measurement of detecting the boundary position can be determined.

[0014]

Preferably, an ultrasonic diagnostic apparatus according to the present invention includes that the predetermined cycle includes a heartbeat cycle of a blood flow that flows through the blood vessel. With this configuration, a region range including an allowable error range added to a movement track in the immediately preceding cycle can be compared with a movement track in the subsequent measurement cycle in synchronization with the heartbeat cycle.

[0015]

Preferably, an ultrasonic diagnostic apparatus according to the present invention further includes an average processing unit provided to perform average processing of data representing the movement amount of the blood vessel wall that is detected by the echo brightness detection unit based on data representing a movement amount obtained a predetermined number or more of cycles before. With this configuration, the stability of the measurement of detecting the movement amount of the blood vessel wall can be determined.

[0016]

[Modes for Carrying Out the Invention]

The following describes embodiments of the present invention, with reference to the drawings.

[0017]

(Embodiment 1)

Fig. 1 is a block diagram schematically showing a configuration of an ultrasonic diagnostic apparatus 100 according to Embodiment 1 of the

present invention. The ultrasonic diagnostic apparatus 100 includes a transmission unit 4. The transmission unit 4 generates an ultrasonic pulse and supplies it to an ultrasonic probe 101. The ultrasonic probe 101 transmits the ultrasonic pulse supplied from the transmission unit 4 from the surface of the skin of a living body toward the blood vessel 10 inside thereof.

[0018]

The blood vessel 10 includes blood vessel walls 103 and 105 that are configured to define a blood flow region 104 through which blood flows. The blood vessel wall 103 constitutes the anterior wall on a side closer to the ultrasonic probe 101 and the blood vessel wall 105 constitutes the posterior wall on a side farther from the ultrasonic probe 101. The blood vessel wall 105 has an atheroma 106 as a local lesion that developed on an inner surface thereof.

[0019]

The ultrasonic diagnostic apparatus 100 is provided with a region of interest placement unit 6. The region of interest placement unit 6 places the region of interest (ROI) 107, which is for obtaining hardness values of tissues along the depth direction from the surface of the skin, so that the the region of interest lies over at least one of the anterior wall 103 and the posterior wall 105.

[0020]

An ultrasonic pulse reflected by the blood vessel 10 is received by an ultrasonic probe 101, and is imparted to a movement detection unit 3 via a reception unit 110 and a delay synthesis unit 111.

[0021]

The movement detection unit 3 detects a movement amount along a

depth direction from the surface of the skin based on the ultrasonic pulse received by the ultrasonic probe 101.

[0022]

The ultrasonic diagnostic apparatus 100 includes a hardness value conversion unit 2. The hardness value conversion unit 2 converts a movement amount detected by the movement detection unit 3 into a hardness value of tissues along the depth direction from the surface of the skin.

[0023]

The ultrasonic diagnostic apparatus 100 includes a boundary position detection unit 1. The boundary position detection unit 1 detects a boundary position between the blood vessel wall 105 constituting the blood vessel 10 and the blood flow region 104 where blood flows through the blood vessel 10 based on the hardness value of tissues along the depth direction. The boundary position detection unit 1 further generates a two-dimensionally mapped color display image showing a cross section of the blood vessel 10, and supplies it to an image synthesis unit 116.

[0024]

The ultrasonic diagnostic apparatus 100 includes a B-mode processing unit 113. The B-mode processing unit 113 generates image information representing a cross section of the blood vessel 10 based on the ultrasonic pulse supplied via a delay synthesis unit 111, and supplies it to the image synthesis unit 116.

[0025]

The image synthesis unit 116 synthesizes the image information supplied from the B-mode processing unit 113 and the image information supplied from the boundary position detection unit 1, and displays the

resultant on a monitor of a display unit 8.

[0026]

Fig. 2 is a schematic view for explaining an operation of the ultrasonic diagnostic apparatus 100 according to the present embodiment. This Fig.2 shows a case where a boundary position between the blood vessel wall 105 and the blood flow region 104 is detected by utilizing echo brightness detected by an echo brightness detection unit 3 based on the ultrasonic pulse reflected by the blood vessel 10, and a case where a boundary position is detected by utilizing a hardness value of tissues converted by the hardness value conversion unit 2.

[0027]

Attention is given to point R0, point R1 and point R2 on a scanning line 220 that shows the course of an ultrasonic pulse. Point R0 is placed inside of the blood flow region 104, point R1 is placed at the boundary position between the blood vessel wall 105 and the blood flow region 104, point R2 is placed in the atheroma 106 on the blood vessel wall 105.

[0028]

As shown by the diagram of Fig. 2 that shows a relationship between the echo brightness that is detected by the echo brightness detection unit 3 and the depth from the surface of the skin, the echo brightness has a characteristic to moderately vary from point G0 corresponding to the blood flow region 104 to point G2 corresponding to the inside of the atheroma 106 via point G1 corresponding to the boundary position between the blood vessel wall 105 and the blood flow region 104. Thus, when point G1 corresponding to the boundary position is to be detected, there is a strong possibility that error may occur in the direction from point G1 to point G0 and in the direction from point G1 to point G2.

[0029]

Therefore, when the measurement of a blood vessel with an atheroma is attempted, which requires detailed diagnosis, there is a strong possibility that depending on the compositions of contents making up the atheroma, unevenness of the echo brightness may occur. Thus, it is impossible to detect the boundary position between the blood vessel wall 105 and the blood flow region 104 accurately.

[0030]

The use of hardness values of tissues converted by the hardness value conversion unit 2 as in this embodiment allows point E1, corresponding to point R1 placed at the boundary position between the blood vessel wall 105 and the blood flow region 104, to show a much higher peak value than those of point E0 corresponding to point R0 placed at the blood flow region 104 and point E2 corresponding to point R2 placed in the atheroma 106, being free from the influence of the echo brightness. Thus, a boundary position between the blood vessel wall 105 and the blood flow region 104 can be detected accurately and securely.

[0031]

As stated above, according to the present embodiment, the boundary position detection unit 1 detects point R1 which shows the boundary position between the blood vessel wall 105 constituting the blood vessel 10 and the blood flow region 104 where the blood flows through the blood vessel 10, based on the hardness values of tissues along the depth direction from the surface of the skin. Therefore, the boundary position between the blood vessel wall and the blood flow region can be detected correctly without the influence of a variation in brightness value of an inner membrane existing in the subject even in the case where there is a local lesion such as an

atheroma in the blood vessel.

[0032]

Fig. 3 is a diagram for explaining an another operation of the ultrasonic diagnostic apparatus 100 according to the present embodiment. The same reference numerals are assigned to the same elements as mentioned above by referring to Figs. 1 and 2. Accordingly, the detailed explanations for these elements are omitted.

[0033]

As shown in Fig. 3, a plurality of ultrasonic pulses shown by a plurality of scanning lines 220 may be applied along the longitudinal direction of the blood vessel 10, and a boundary position detection unit 1 so as to detect a boundary position along the longitudinal direction of the blood vessel 10.

[0034]

With this configuration, an image can be generated that does not include information on the hardness of tissues of blood flow components existing in the region of interest (RIO) 107 that are unnecessary for diagnosis by deleting the information two-dimensionally.

[0035]

(Embodiment 2)

As referred to in Fig. 1, the ultrasonic diagnostic apparatus 100 is further provided with the filter processing unit 7. The filter processing unit 7 is provided to perform filter processing of data detected by the boundary position detection unit 1 that shows the boundary position along the longitudinal direction of the blood vessel 10.

[0036]

Fig. 4 is a schematic view for explaining still another operation of

the ultrasonic diagnostic apparatus 100 according to the present embodiment. Fig. 4 shows the boundary detection results within the region of interest (ROI) 107 obtained for each specific cycle such as a heartbeat cycle, which are shown as a frame 410 and a frame 420 in the order of their detected time.

[0037]

In the actual site for diagnosis, there is a possibility of the mixing of noise into tracking information on a displacement of the movement of a blood vessel wall, resulting from a plurality of factors such as the movement of the subject and his/her respiratory state, as well as the fixed state of the ultrasonic probe 101. As a result, noise 413 and noise 429 would be mixed in the boundary detection of the blood vessel wall.

[0038]

In order to minimize the influence of such noise, the filter processing unit 7 performs the filter processing of boundary detection positions concerning mutually neighboring plural positions as in the following expressions (1) and (2) where the boundary detection position at position f is defined as K(f).

[0039]

[Expression 1]

$$K(403) = \{K(412) + K(413) + K(414)\}/3 \cdots (1)$$

[0040]

[Expression 2]

$$K(409) = \{K(428) + K(429) + K(430)\}/3 \cdots (2)$$

[0041]

Further, in order to make a comparison with a result obtained a predetermined number of cycles before, the filter processing according to the

following expressions (3) and (4) may be performed, whereby a boundary detection image as in the frame 400 can be generated with a minimized influence of noise:

[0042]

[Expression 3]

$$K(403) = \{K(413) + K(423)\}/2 \quad \cdots (3)$$

[0043]

[Expression 4]

$$K(409) = \{K(419) + K(429)\}/2 \quad \cdots (4).$$

[0044]

Herein, for the simplification of description, an example using values at left and right adjacent points are illustrated, which is not limited in the present invention. Values at left and right two or more points each may be used for the filter processing, from which similar effects can be obtained.

[0045]

Further, although the above example describes the filter processing using the simple arithmetic mean, weighting for the filter processing may be modified, the arithmetic expressions may be modified, or a plurality of filtering processes may be combined. Moreover, with respect to the movement amounts of the amplitude displacement of the blood vessel wall that is not subjected to the boundary detection, various filtering processes may be applied, followed by the boundary detection.

[0046]

In this way, even in the case where noise is mixed into tracking information on a displacement of the movement of a blood vessel wall due to a plurality of factors such as the movement of the subject, his/her

respiratory state and the fixed state of the ultrasonic probe, an improved ultrasonic diagnostic apparatus can be provided wherein a boundary detection image with a minimized influence of the noise can be generated.

[0047]

(Embodiment 3)

An ultrasonic diagnostic apparatus 100 further is provided with the average processing unit 9 and the stability determination unit 31 in addition, as shown in Fig. 1. The average processing unit 9 is provided to perform average processing of data showing a boundary position detected by the boundary position detection unit 1 based on data showing a boundary position obtained a predetermined number or more of cycles before. The stability determination unit 31 determines stability of the measurement of detecting the boundary position between the blood vessel wall 105 and the blood flow region 104 based on the data subjected to the average processing by the average processing unit 9.

[0048]

Fig. 5 is a schematic view for explaining a still another operation of the ultrasonic diagnostic apparatus 100 according to the present embodiment. When ideal measurement data can be obtained in a constant state of the positional relationship between the subject and the ultrasonic probe 101 or in a stable state of the subject by stopping his/her breathing, the blood vessel wall has similar movement tracks in heartbeats. The stability of the measurement itself of detecting the boundary position between the blood vessel wall 105 and the blood flow region 104 is determined by utilizing this.

[0049]

For instance, a region range including an allowable error range 511

added to a movement track 510 in the immediately preceding cycle in synchronization with the heartbeat cycle of the ECG waveform 500 is compared with a movement track in a subsequent measurement cycle. In the case where the entire movement track falls within the region range including the allowable error range 511 added to, as in the movement track 520 when the data is stably determined, the measurement is determined to be stable. In the case where the movement track that deviates from the region range including the allowable error range 511 added to is present, as in the movement track 530 when the data is not stably determined, the measurement is determined to be unstable.

[0050]

When a measurer is notified of such information indicating stable measurement or unstable measurement in real time, it becomes possible for the measurer to determine during the measurement as to whether the current measurement result is reliable or not. As a result, the measuring time can be shortened.

[0051]

Certainly, the determination concerning stable measurement or unstable measurement may be made based on a difference between the measurement result in the present cycle and that in the immediately preceding cycle. Further, the determination concerning stable measurement or unstable measurement may be made based on the comparison with not only the immediately preceding cycle but also stably measured movement tracks in a plurality of past cycles.

[0052]

Further, the threshold value (allowable error 511) for the determination concerning stable measurement or unstable measurement

may be changed. Moreover, regarding values determined from an echo brightness value that is unsuitable for boundary determination, such as a value of pseudo boundary determination position, a value obtained in the immediately preceding cycle and a value obtained in the present cycle may be compared with each other. Consequently, by combining these plural functions of determining measuring stability, the reliability of a measurement result can be enhanced further.

[0053]

In this way, by utilizing a similarity in movement tracks of the blood vessel wall among heartbeats when ideal measurement data is obtained in a constant state of the positional relationship between the subject and the ultrasonic probe 101 or in a stable state of the subject by stopping his/her breathing, the stability of the measurement of detecting the boundary position between the blood vessel wall 105 and the blood flow region 104 can be determined. When a measurer is notified of such information in real time, it becomes possible for the measurer to determine during the measurement as to whether the current measurement result is reliable or not. As a result, an improved ultrasonic diagnostic apparatus that is capable of shortening the measuring time can be provided.

[0054]

[Effects of the Invention]

According to the present invention as described above, an ultrasonic diagnostic apparatus capable of measuring a state of a blood vessel correctly using ultrasonic waves can be provided.

[Brief Description of the Drawings]

[FIG. 1] A block diagram schematically showing a configuration of an ultrasonic diagnostic apparatus according to Embodiment 1 of the

present invention.

[FIG 2] A schematic view for explaining an operation of the ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention.

[FIG 3] A schematic view for explaining another operation of the ultrasonic diagnostic apparatus according to Embodiment 1 of the present invention.

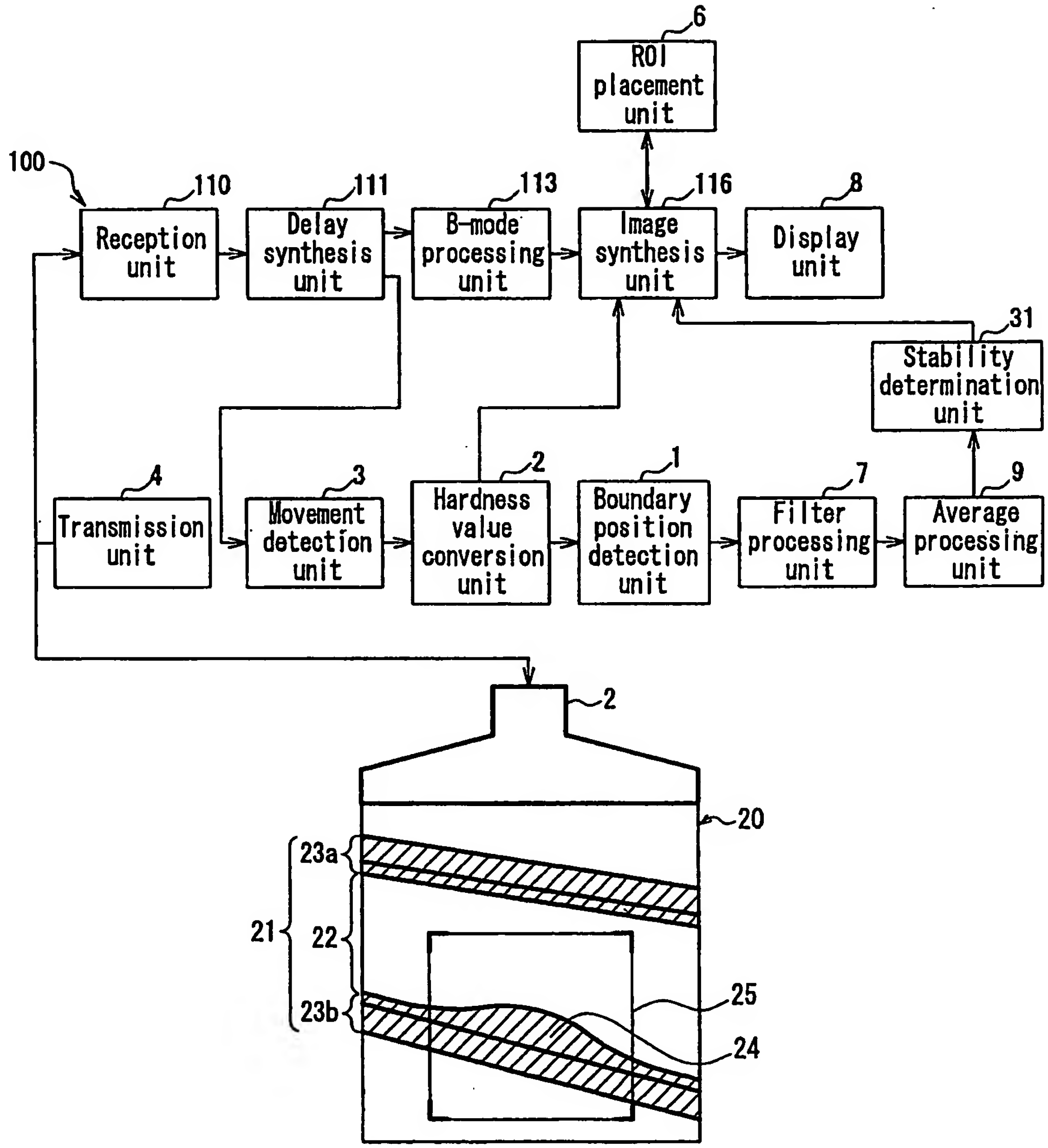
[FIG 4] A schematic view for explaining an operation of the ultrasonic diagnostic apparatus according to Embodiment 2 of the present invention.

[FIG 5] A schematic view for explaining an operation of the ultrasonic diagnostic apparatus according to Embodiment 3 of the present invention.

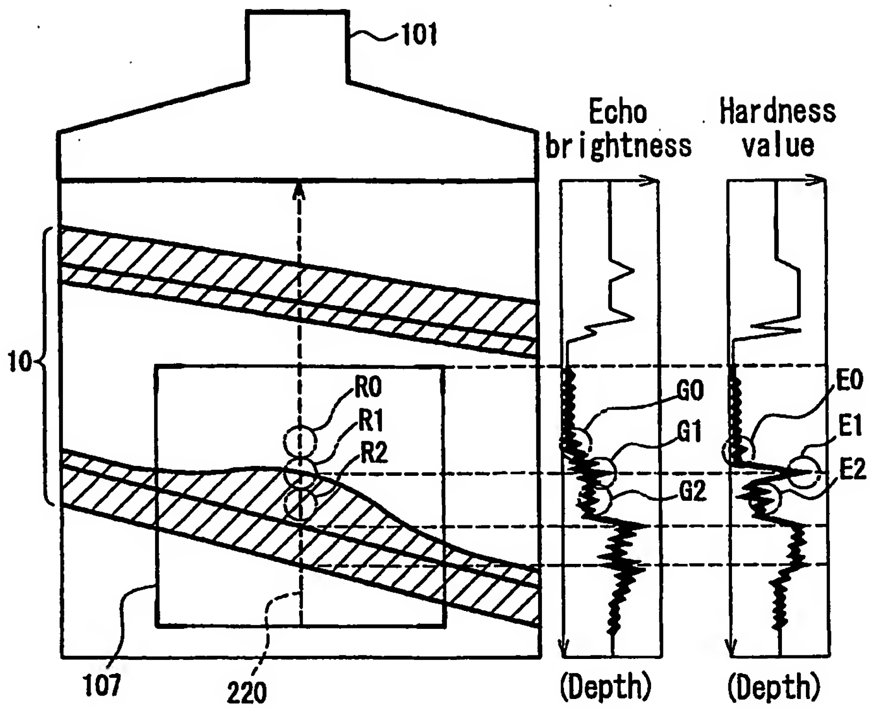
[Description of the Reference Numerals]

1	boundary position detection unit
2	hardness value conversion unit
3	echo brightness detection unit
4	transmission unit
6	region of interest placement unit
7	filter processing unit
8	display unit
9	average processing unit
10	blood vessel

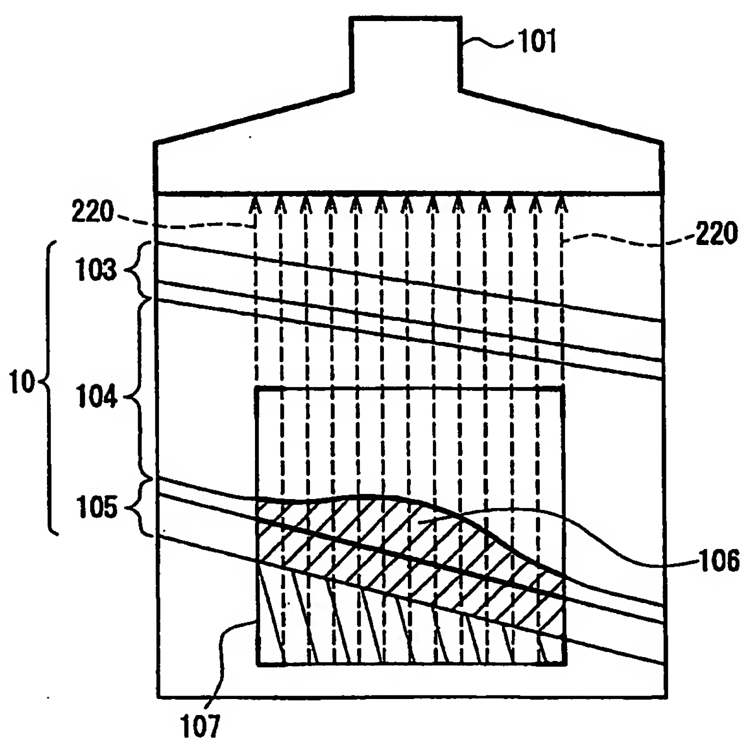
[Document Name] Drawings
[FIG. 1]



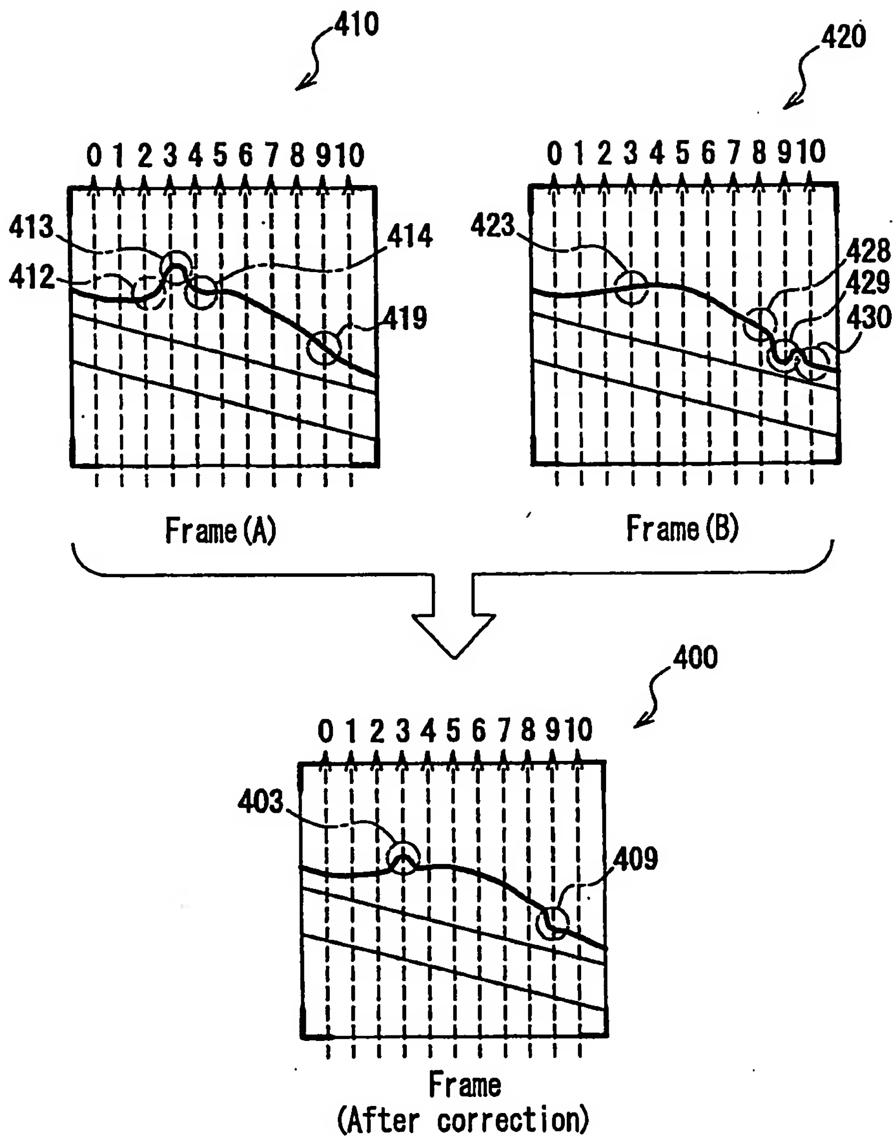
[FIG. 2]


101
Echo brightness
Hardness value
10
R0
R1
R2
G0
G1
G2
E0
E1
E2
107
220
(Depth)
(Depth)

[FIG. 3]


101
220
220
10
103
104
105
106
107

[FIG. 4]


410
420
0 1 2 3 4 5 6 7 8 9 10
413
412
414
419
423
428
429
430
Frame (A)
Frame (B)
400
403
409
Frame
(After correction)

[Document Name] ABSTRACT

[Abstract]

[Objective] To provide an ultrasonic diagnostic apparatus that is capable of correctly measuring a status of a blood vessel using ultrasonic waves.

[Means for Solving the Problem] An ultrasonic diagnostic apparatus 100 includes a transmission unit 4 that transmits at least one ultrasonic pulse from a surface of a skin of a subject toward a blood vessel of the subject, a reception unit 110 that receives an ultrasonic echo along a depth direction from the surface of the skin and converts the same into an electric signal based on an ultrasonic echo signal reflected by the blood vessel, a movement detection unit 3 that analyzes a phase of an ultrasonic echo signal in a direction intersecting a center axis of the blood vessel so as to calculate a movement amount of the blood vessel wall; and a hardness value conversion unit 2 that converts a phase change of an ultrasonic echo signal into a hardness value of tissues along a depth direction from the surface of the skin, and a boundary position detection unit 1 that detects a boundary position between a blood vessel wall and a blood flow region based on a hardness value of tissues along the depth direction.

[Selected Figure] FIG. 1